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ORIGINAL RESEARCH

Four or six implants in the maxillary posterior region to support an overdenture: 5-year results from a randomized controlled trial

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Abstract

Objective: To compare clinical and patient-reported outcomes when providing maxillary overdentures on four bar- and six bar-connected implants placed in the posterior region during a 5-year follow-up period.

Materials and methods: Sixty-six fully edentulous patients with functional maxillary denture complaints and insufficient bone volume to allow implant placement were scheduled for a maxillary sinus floor elevation procedure with bone from the anterior iliac crest and randomized to receive either four or six implants in the posterior maxilla and four implants in the mandible. After 3 months of osseointegration, a bar-supported overdenture was constructed. Maxillary implant survival, overdenture survival, clinical scores, peri-implant bone height changes and patient satisfaction were assessed.

Results: Sixty patients completed the 5-year follow-up. Implant survival was 100% in the four-implant group and 99.5% in the six-implant group. No new overdentures had to be made in the four-implant group, and three new overdentures were made in the six-implant group due to excessive wear of the denture base and teeth (90.9% overdenture survival). Clinical parameters did not differ significantly between groups. Mean marginal bone loss compared to baseline was 0.58 ± 0.51 mm in the four-implant group and 0.60 ± 0.58 mm in the six-implant group, respectively. Overall, patient satisfaction improved significantly, but did not differ between groups.

Conclusion: Following a bilateral maxillary sinus floor elevation procedure, a bar-supported overdenture on four implants in the posterior maxillary region is not inferior to an overdenture supported by six implants after a 5-year evaluation period in patients with functional maxillary denture complaints and marked posterior resorption (Clinical trial registration number: NTR2969).

KEYWORDS

dental implants, edentulous, maxilla, overdenture, healthy aging

1 | INTRODUCTION

Implant overdenture therapy improves function, comfort, diet and patient satisfaction (Fromentin, Lassauzay, Abi Nader, Feine, & de Albuquerque Junior, 2010; Van Assche, Michels, Quirynen, and Naert (2012); Boven, Raghoobar, Vissink, & Meijer, 2015). Both in the mandible and in the maxilla, overdenture treatment is associated with a high survival rate (Raghoobar, Meijer, Slot, Slater, & Vissink, 2014; Rocuzzo, Bonino, Gaudio, Zwahlen, & Meijer, 2012; Sadowsky & Zitzmann, 2016; Slot, Raghoobar, Vissink, Huddleston Slater, & Meijer, 2010). However, the optimal number and position of implants and the optimal type of attachment system are still unclear.

In recent years, several systematic reviews have focused on maxillary overdentures, and their findings have been generally consistent (Raghoobar et al., 2014). After one year of functional use, Slot et al. (2010) reported an implant survival rate of 98.2% for six implants with bar anchorage, a survival rate of 96.3% for four implants with bar anchorage and a survival rate of 95.2% for four implants with a ball anchorage. Rocuzzo et al. (2012) concluded that maxillary overdenture treatment appeared to be very successful, but they could not draw conclusions on the optimal number of implants needed to support a maxillary overdenture. Sadowsky and Zitzmann (2016) concluded that a maxillary overdenture supported by four to six implants without palatal coverage offers a stabilized removable solution for the edentulous maxilla, which provides increased patient satisfaction and quality of life improvement.

The results of four bar- and six bar-splinted implants seem comparable, and both have favorable one-year outcomes, but no studies on these implants have been conducted with longer evaluation periods, and it remains unclear whether six implants are needed to support an implant-retained maxillary overdenture or whether fewer implants could suffice. Only one randomized controlled trial with an observation period exceeding 5 years has been published. This trial evaluated the treatment outcome of four and six anteriorly positioned implants to support maxillary overdentures (Slot, Raghoobar, Cune, Vissink, & Meijer, 2016). Implant survival was 100% in the four-implant group and 99.2% in the six-implant group. Overdenture survival was 100% in both groups. Other studies that reported 5-year results or longer are prospective case series in which implants with a roughened surface were used (Eerdekens, Schols, Coelst, Quirynen, & Naert, 2015; Ferrigno, Laureti, Fanali, & Grippaudo, 2002; Mangano et al., 2011). Ferrigno et al. (2002) studied 35 patients with four or six implants and bar retention. Implant survival after 10 years with four implants was 86.9%, and with six implants, it was 92.2%. Mangano et al. (2011) reported a 5-year implant survival rate of 97.4% in a study with 38 patients having four implants and bar retention. Eerdekens et al. (2015) reported a 5-year implant survival rate of 96.6% in a study with 10 patients having six cone-anchored implants. Besides the lack of randomized controlled studies reporting on the treatment outcome of maxillary implant-retained overdentures, no treatment guidelines are available on preferable positioning of the implants. If

sufficient bone is present in the anterior region and sufficient space is available in the overdenture to cover an attachment system, placing implants in the anterior region is advantageous. In this situation, extensive bone augmentation procedures (maxillary sinus floor elevation surgery with bone from the iliac crest) can be avoided, resulting in less morbidity and less treatment time (Kalk, Raghoobar, Jansma, & Boering, 1996; Slot, Raghoobar, Vissink, & Meijer, 2014). Several authors reported that the patients in their study populations did not require extensive bone augmentation procedures for the implants to be positioned in the anterior region.

However, patients with poor retention and stability of their conventional maxillary denture often have limited bone volume to place implants. Therefore, these implants often have to be positioned in the posterior part of the maxilla, preceded by or in conjunction with a bone augmentation procedure.

No studies have yet compared the outcomes of four implants with six implants in the posterior region of the maxilla with a longer follow-up period. We therefore conducted a 5-year randomized controlled trial with parallel design in which we compared the treatment outcome (peri-implant bone height changes, peri-implant health, implant survival, overdenture survival and patients' satisfaction) of maxillary overdentures placed on four bar-connected implants in the posterior region of the maxilla with the outcomes of six bar-connected implants in the same region.

2 | MATERIALS AND METHODS

We reported previously on the details of the treatment and evaluation procedures (Slot et al., 2014). A summary of the procedures is included below.

2.1 | Patient selection

Participants in the study were selected from fully edentulous patients referred to the Department of Oral and Maxillofacial Surgery (University Medical Center Groningen, the Netherlands) suffering from a lack of retention and stability of both the upper denture and lower denture based on the following inclusion criteria: at least 18 years of age, capable of understanding and giving informed consent, at least one year edentulous in the maxilla and mandible and insufficient volume of bone of the maxilla (<3 mm in width and <5 mm in height) for inserting implants. Excluded were patients with an American Society of Anesthesiologists (ASA) score \geq III (Smeets, De Jong, & Abraham-Inpijn, 1998), those currently smoking, and those with a history of radiotherapy in the head and neck region or a history of pre-prosthetic surgery and previous implant placement or sinus pathology. The study was approved by the Medical Ethics Committee of the University Medical Center Groningen (ABR NL32503.042.11). CONSORT guidelines for reporting clinical trials were followed.

Panoramic radiographs, lateral cephalograms and postero-anterior oblique radiographs were made to assess the volume of the

maxillary alveolar bone, the dimensions of the maxillary sinus and the anteroposterior relationship of the maxilla to the mandible.

2.2 | Treatment procedure

All surgical procedures were performed by one experienced oral and maxillofacial surgeon (G.M.R.). The prosthetic procedures were conducted by three experienced prosthodontists, and manufacturing of the superstructure was done by a single experienced dental laboratory.

2.3 | Surgical procedures

Patients were randomly allocated to one of the treatment groups by lot with the use of sealed envelopes. Thirty-three notes with the words "4 implants" and 33 notes with the words "6 implants" were put into 66 identical, sequentially numbered, non-transparent envelopes. No stratification was performed. All envelopes were irreversibly sealed, only to be opened prior to the fabrication of the surgical template.

A maxillary sinus augmentation procedure with bone from the iliac crest was performed on both sides (Raghoobar, Timmenga, Reintsema, Stegenga, & Vissink, 2001; Raghoobar, Vissink, Reintsema, & Batenburg, 1997). After a 3-month healing period, either four or six dental implants (Straumann Standard SLA® implants; Ø 4.1 mm, length 12 mm, RN, Institut Straumann AG, Basel, Switzerland), depending on randomization group, were inserted in the maxilla in a single-step procedure. The implants were placed into the grafted sites in predefined positions (positions 16, middle of 15/14, 13, 23, middle of 24/25, 26 in the six-implant group and positions 16, 13, 23, 26 in the four-implant group) using a template designed for semi-guided implant placement.

2.4 | Prosthetic procedures

Prosthetic procedures commenced after 3 months of undisturbed healing. The final superstructure consisted of a milled titanium split bar (Figures 1 and 2) and an overdenture with built-in cobalt chromium reinforcement structure and gold retentive clips (Slot, Raghoobar, Van Dijk, & Meijer, 2012). Resilient egg-shape bars (width 2.19 mm) were used (ES Healthcare NV, Hasselt, Belgium). The overdentures were designed with full coverage of the alveolar process, but without palatal coverage in the maxilla. A bilateral balanced occlusion concept was followed. All patients received also a four-implant overdenture in the mandible. Patients were instructed about hygiene procedures associated with the dentures and the bars. They were advised to remove the overdenture at night. Subsequently, the patients were scheduled for routine yearly maintenance appointments with a prosthodontist, combined with a dental hygienist.

2.5 | Outcome measures

The primary outcome measure was peri-implant bone height changes. The secondary outcome measures were implant survival,

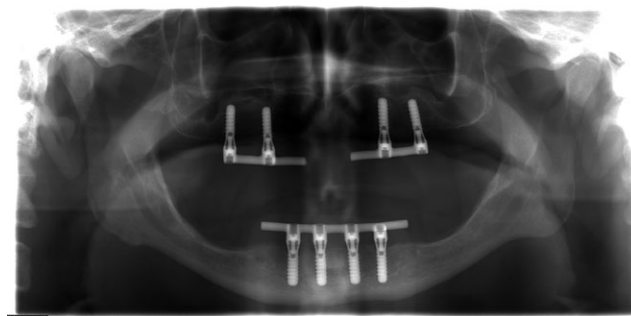


FIGURE 1 Five-year panoramic radiograph of a patient with four implants connected with a bar in the posterior region of the maxilla

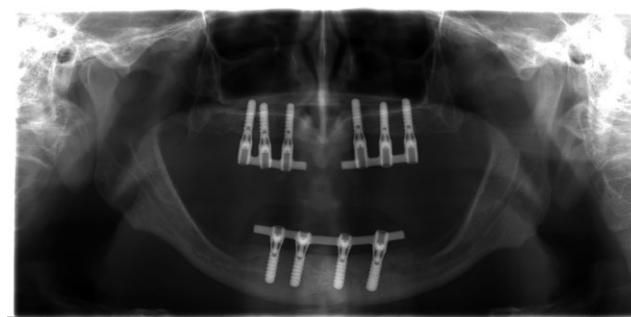


FIGURE 2 Five-year panoramic radiograph of a patient with six implants connected with a bar in the posterior region of the maxilla

overdenture survival and soft tissue conditions (plaque index, presence of calculus, gingival index, sulcus bleeding index and pocket probing depth). These parameters were scored at placement of the overdenture, and one year and five years after loading. All measurements were taken by a single examiner (W.S.). Patients' satisfaction was also scored before treatment, and one year and five years after loading.

2.6 | Change of radiographic bone level

Standardized intraoral radiographs were taken at placement of the overdenture, after 1 year and again at 5 years after placement. The radiographs were taken according to a long-cone paralleling technique with an individualized X-ray holder described by Meijndert, Meijer, Raghoobar, and Vissink (2004). The digital images were analyzed using computer software (Biomedical Engineering, University Medical Center Groningen, the Netherlands) to perform linear measurements on digital radiographs. The known implant dimension was used as a reference to transform the linear measurements into mm. Peri-implant bone height change was defined as the difference in bone height between the X-ray taken at overdenture placement and after 1 and 5 years. Data collection and analysis of the radiographs were done by the same observer. The worst score per implant of the clinical and radiographic parameters

was used in the data analysis. Reproducibility of the specific analysis method was evaluated by Telleman, Raghoobar, Vissink, and Meijer (2013). The intraclass correlation coefficient for average measures was 0.867 for the radiographic interobserver agreement (Cronbach's $\alpha = 0.867$), which can be interpreted as almost perfect agreement.

2.7 | Clinical parameters

For presence of plaque, the index according to Mombelli, Van Oosten, Schürch, and Lang (1987) was used. The presence of calculus (score 1) or the absence of calculus (score 0) was scored. To qualify the degree of peri-implant inflammation, the modified Löe and Silness (1963) index was used. For bleeding, the bleeding index according to Mombelli et al. (1987) was used. Probing depth was measured at four sites of each implant (mesial, labial, distal and lingual) by using a manual periodontal probe (Williams Colour-Coded Probe; Hu-Friedy, Chicago, IL, USA).

Peri-implant mucositis and peri-implantitis were calculated at patient level. As a definition for peri-implant mucositis and peri-implantitis, the consensus reached at the Seventh European Workshop on Periodontology was used (Lang & Berglundh, 2011):

- peri-implant mucositis (radiographic bone loss <2 mm): Bleeding on probing and/or suppuration and
- peri-implantitis: Bleeding on probing and/or suppuration in combination with marginal bone loss ≥ 2 mm.

2.8 | Patient satisfaction

A Patient-reported outcome measures (PROMs) were assessed using a validated questionnaire (Vervoorn, Duinkerke, Luteijn, & Van Der Poel, 1988). Items were functional problems of the upper denture, functional problem complaints in general, problems concerning facial esthetics, items concerning accidental lip, cheek and tongue biting ("neutral space"), and items concerning esthetics of the denture.

The severity of each complaint could be expressed on a 4-point rating scale (0 = no complaints, 1 = little, 2 = moderate and 3 = severe complaints).

All patients were requested to fill out a "Chewing ability" questionnaire (Stellingsma, Slagter, Stegenga, Raghoobar, & Meijer, 2005). In this questionnaire, patients gave their opinion about the ability to chew nine different kinds of food on a 3-point rating scale (0 = good, 1 = moderate and 2 = bad). The items were grouped into three scales: soft food, tough food and hard food. In addition to these questionnaires, the patients' overall denture satisfaction was expressed on a 10-point rating scale (1 = very bad to 10 = excellent).

Patients' satisfaction was scored before treatment and 1 and 5 years after placement of the overdenture.

2.9 | Statistical analysis

It was assumed that an implant-supported overdenture on four implants was not inferior to one supported by six implants (non-inferiority hypothesis). The sample size was calculated with the program G*power version 2 (Erdfelder, Faul, & Buchner, 1996). Peri-implant bone changes were regarded as primary outcome for the power analysis. A difference of at least 0.4 mm in bone height (measured on standardized radiographs, with a standard deviation of 0.5 mm) between the four-implant group and six-implant group after twelve months was expected to differentiate between the two groups, based on the findings of a study on maxillary implant-supported overdentures (Raghoobar, Schoen, Meijer, Stellingsma, & Vissink, 2003). A t test given $\alpha = 0.05$ with a power of 90% combined with the expected effect size for two independent means returns a sample size of 28 persons in each group. To deal with withdrawal of individuals in the study, the number of participants was set at 33 persons per group.

Data were analyzed using the Statistical Package for Social sciences (version 18.0, SPSS, IBM Corporation, Chicago, IL, USA). In all tests, a significance level of 0.05 was used. To test whether the result from the frequency analyses differed significantly from a normal distribution, qq-normal plots and the Shapiro-Wilk test were done. For normally distributed data, differences between study groups were tested with an independent Student's t test. For non-normally distributed data, Mann-Whitney tests were used. For comparisons over time, Wilcoxon signed-rank tests were applied.

3 | RESULTS

Between January 2006 and December 2009, consecutive patients fulfilling the criteria were included. All 33 patients in the four-implant group completed the 1-year evaluation period. After five years, two patients in this group had died, one patient did not attend the evaluation due to illness, and one patient moved abroad. This resulted in 29 patients in the four-implant group for the 5-year evaluation). All 33 patients in the six-implant group completed the 1-year evaluation period. After 5 years, one patient did not attend the evaluation due to illness and one patient moved without forwarding his address. This resulted in 31 patients in the six-implant group for the 5-year evaluation.

No implants were lost in the four-implant group, while one implant was lost in the six-implant group (position 16) during the osseointegration period. Because a bar-supported overdenture could still be made on the remaining five implants, there was no need to replace this single implant. The 5-year implant survival rate was 100% in the four-implant group and 99.5% in the six-implant group.

Mean loss of peri-implant bone between baseline and the 5-years evaluation was 0.58 ± 0.51 mm in the four-implant group and 0.60 ± 0.58 in the six-implant group, and did not significantly differ between the groups (Table 1). Median scores of indices for plaque, calculus, gingiva and bleeding were very low after 5 years of loading, and again did not significantly differ between the groups, nor

TABLE 1 Mean values and standard deviations of marginal bone loss in mm, and frequency distribution of bone loss at 1 and 5 years after placement of the overdenture of the four- and six-implant groups, and significance level (*p* value) of differences ($p < 0.05$) between the groups

	1 year			5 years		
	Four-implant group (<i>n</i> = 132 implants)	Six-implant group (<i>n</i> = 197 implants)	<i>p</i> value	Four-implant group (<i>n</i> = 116 implants)	Six-implant group (<i>n</i> = 185 implants)	<i>p</i> value
Mean (SD)	0.35 mm (0.31)	0.46 mm (0.34)	$p = 0.150$	0.58 mm (0.51)	0.60 mm (0.58)	$p = 0.871$
0–0.5 mm	79%	91%		45%	58%	
>0.5–1.0 mm	15%	6%		38%	13%	
>1.0–1.5 mm	6%	3%		17%	19%	
>1.5–2.0 mm	0%	0%		0%	7%	
>2.0 mm	0%	0%		0%	3%	

did the mean scores for pocket probing depth (Table 2). In the present study, incidence at patient level of peri-implant mucositis was 27.3% in the four-implant group and 39.4% in the six-implant group. Incidence at patient level of peri-implantitis was 17.2% in the four-implant group and 9.7% in the six-implant group. Mean scores of the questionnaires focusing on denture complaints, chewing ability and overall satisfaction score of patients are listed in Table 3 with no significant differences between the groups. The surgical and prosthetic aftercare during five years of follow-up revealed a small number of events, mostly repair of the denture base or teeth (Table 4). No new overdentures had to be made in the four-implant group, and three new overdentures were made in the six-implant group due to excessive wear of the denture base and teeth (90.9% overdenture survival).

With regard to the changes in peri-implant health over time (Table 2), some worsening, albeit comparable for the two groups, of the peri-implant health was observed. It should be marked, however, that this worsening is mainly a shift from the 0 to 1 category, which still reflects a good peri-implant health in most patients. With regard to the patient-reported outcome measures (PROMs), both the various PROMs remained at a high level, compared to pre-treatment condition, and did not significantly change between the 1- and 5-year results (Table 3).

4 | DISCUSSION

Our study shows that both four and six dental implants connected with a bar, placed in the posterior region of the edentulous maxilla, can effectively support an overdenture. We found no significant differences in any of the parameters between the group with an overdenture supported by four implants and the group with an overdenture supported by six implants.

Five-year survival rate of the implants was high in both groups (100% and 99.5%, respectively). It is promising that from the start of functional loading no implants were lost in either group. This is comparable to the findings of Mangano et al. (2011), Eerdekens et al. (2015) and Slot et al. (2016), who used implants with a roughened surface, as in the present study, and reported 5-years' implant survival of 96.6%–99.2%. Although this has not yet been analyzed in a study comparing various implant designs, implants with a roughened

surface apparently perform better than implants with a machined surface in the edentulous maxilla when used to support an overdenture.

The mean peri-implant bone loss between baseline (placement of the overdenture) and the 5-year evaluation was very small in both groups. This is again comparable to those reported by Mangano et al. (2011), Eerdekens et al. (2015) and Slot et al. (2016), who reported values of 0.5–0.7 mm. In the present study, peri-implant bone changes were analyzed at implant level without clustering within the same patient, which could be addressed as a limitation. Mean indices for plaque, calculus, gingiva and bleeding were very low at the 5-year evaluation, and the probing depth was not deviating. There were no differences in outcome between four- and six-implant group. Some extra effort in performing hygiene tasks might be required from patients with six implants, but this did not appear to affect the results.

Incidence of peri-implantitis was calculated according to the definition of VII European Workshop on Periodontology (Lang & Berglundh, 2011). For the maxilla, one study has reported on peri-implantitis of patients with an implant-supported overdenture, although in this study implants were placed in the anterior region without a procedure of sinus elevation with iliac crest bone (Slot et al., 2016). In that study, the incidence at the patient level of peri-implantitis was 8.3% in a group with four implants. Of a group with six implants, they reported an incidence of peri-implantitis being 4.5%. These numbers are lower than those in the present study. A possible explanation for this discrepancy could be that oral hygiene is easier to perform in the anterior region than in the posterior region, although this is not supported by the plaque scores in both groups. Another possibility could be that the bone present after the often more extended augmentation procedures in the posterior region is less stable than bone in the anterior region. Only one single observer collected all the scores (clinical and radiographic) throughout the study. This could be a limitation with respect to intra-observer reliability.

In our study, patient satisfaction did not differ between the groups. Krennmair, Krainhöfner, and Piehslinger (2008) and Slot et al. (2016) also reported that patients with an overdenture on four or six implants in the maxilla were equally satisfied. It appears that patients' satisfaction is not dependent on the number of implants that support the bar: four or six implants. This could be due to the fact that four and six implants are both placed in approximately the same

TABLE 2 Frequency distribution of plaque, calculus, gingival and bleeding indices and mean and standard deviation (SD) of probing depth in mm, at placement of the overdenture (T_0), and 1 year (T_{12}) and 5 years (T_{60}) after placement of the overdenture, and significance level (p value) of differences between groups at three time points ($p < 0.05$ was considered significant)

	T ₀			T ₁₂			T ₆₀		
	Four-implant group (n = 33)	Six-implant group (n = 33)	p value	Four-implant group (n = 33)	Six-implant group (n = 33)	p value	Four-implant group (n = 29)	Six-implant group (n = 31)	p value
Plaque index (%)									
0	87.9	90.9	1.000	78.8	72.7	0.775	62.1	51.6	0.475
1	12.1	9.1		21.2	27.3		20.7	25.8	
2	0	0		0	0		17.2	22.6	
3	0	0		0	0		0	0	
Calculus index (%)									
0	97.0	100	1.000	93.9	100	0.492	96.6	96.8	1.000
1	3.0	0		6.1	0		3.4	3.2	
Gingival index (%)									
0	87.9	97.0	0.355	81.8	72.7	0.558	48.3	54.8	0.462
1	12.1	3.0		18.2	27.3		41.4	41.9	
2	0	0		0	0		10.3	3.3	
3	0	0		0	0		0	0	
Bleeding index (%)									
0	72.7	72.3	1.000	54.5	45.5	0.487	51.7	38.7	0.268
1	24.3	27.3		45.5	51.5		37.9	41.9	
2	3.0	0		0	0		10.4	19.4	
3	0	0		0	0		0	0	
Probing depth in mm (SD)	4.5 (0.8)	4.1 (1.1)	0.157	4.8 (0.9)	4.4 (1.2)	0.067	4.3 (1.0)	4.2 (0.8)	0.765

TABLE 3 Mean score of five scales concerning the denture complaints, mean scores of chewing ability of soft, tough and hard food and overall satisfaction score before, and 1 and 5 years after treatment, and significance level of differences ($p < 0.05$) between the groups.

	Pre-treatment			1 year			5 years		
	Four-implant group ($n = 33$)	Six-implant group ($n = 33$)	p value	Four-implant group ($n = 33$)	Six-implant group ($n = 33$)	p value	Four-implant group ($n = 29$)	Six-implant group ($n = 31$)	p value
Functional complaints about upper denture (SD)	1.5 (0.6)	1.7 (0.5)	0.099	0.2 (0.2)	0.2 (0.2)	0.931	0.1 (0.1)	0.2 (0.2)	0.212
Functional complaints in general (SD)	1.0 (0.5)	1.1 (0.5)	0.132	0.1 (0.1)	0.2 (0.2)	0.058	0.1 (0.1)	0.1 (0.1)	0.106
Facial esthetics (SD)	1.1 (0.9)	1.1 (1.0)	0.828	0.2 (0.5)	0.2 (0.4)	1.000	0.1 (0.3)	0.4 (0.7)	0.052
"Neutral Space" (SD)	0.6 (0.6)	0.5 (0.7)	0.408	0.3 (0.4)	0.5 (0.5)	0.227	0.4 (0.4)	0.2 (0.4)	0.055
Esthetics (SD)	0.4 (0.3)	0.4 (0.4)	0.877	0.1 (0.2)	0.1 (0.2)	0.883	0.1 (0.2)	0.1 (0.2)	0.508
Soft food (SD)	0.4 (0.4)	0.4 (0.4)	0.632	0.0 (0.1)	0.0 (0.1)	0.310	0.0 (0.0)	0.0 (0.1)	0.338
Tough food (SD)	1.0 (0.5)	1.2 (0.6)	0.332	0.1 (0.2)	0.1 (0.3)	0.410	0.1 (0.3)	0.1 (0.3)	0.688
Hard food (SD)	1.8 (0.4)	1.8 (0.5)	0.730	0.2 (0.5)	0.4 (0.7)	0.191	0.2 (0.5)	0.4 (0.5)	0.140
Overall satisfaction score (SD)	4.4 (1.7)	3.9 (1.5)	0.188	9.0 (0.8)	8.7 (1.0)	0.232	8.6 (0.7)	8.8 (0.9)	0.467

Notes. Differences between study groups were tested with the independent Student's t test.

Denture complaints (possible range: 0–3), mean scores of chewing ability of soft, tough and hard food (possible range: 0–2) and overall satisfaction score (possible range: 1–10)

TABLE 4 Surgical and prosthetic aftercare (number of events) of the four-implant group and the six-implant group during 5 years of follow-up

	Four-implant group (n = 29)	six-implant group (n = 31)
Removal of hyperplasia	2	3
Surgical treatment of peri-implantitis	0	0
Clip repair	0	0
Repair denture base/teeth	13	18
Relining overdenture	0	1
Readjustment occlusion	1	2
New bar	0	1
New overdenture	0	3

area and the fact that the length of the bar is about the same in both designs. After 5 years, patients continued to be very satisfied with their overdentures; these results are rather similar to the 1-year data. The high level of satisfaction with maxillary overdentures, including satisfaction with speech, is similar to that found by Heydecke et al. (2003); they reported favorable results of an overdenture compared with a fixed implant prosthesis.

Prosthetic complications related to treatment were mainly restricted to repair of the denture base and teeth. Mangano et al. (2011) reported that the majority of complications were related to the weakness of the anchorage components connecting the bar and overdenture. In contrast, in the present study no clip repairs were observed. The absence of problems with the attachment system could be caused by a built-in cobalt chromium reinforcement structure and gold retentive clips attached to this structure (Slot et al., 2012).

In a parallel study, patients were treated with either four or six implants in the anterior region of the maxilla and a bar superstructure to support an overdenture. These patients had enough bone to place implants without requiring a sinus elevation procedure with bone from the iliac crest (Slot et al., 2016). Also, in this study no significant difference was found between treatments with four or six implants at all evaluation items. Moreover, comparing outcomes of treatment with implants in the anterior region with treatment in the posterior region, it appears that these are highly comparable at 5 years' follow-up. Consequently, when placement of implants to support an overdenture in the maxilla is determined to be the treatment of choice, we recommend an initial assessment of whether implant placement in the anterior maxillary region is possible. Such a treatment procedure reduces treatment time and morbidity compared to implant placement in the posterior region, as implant placement in the posterior region, particularly in cases with severe resorption or pneumatized maxillary sinuses, usually has to be preceded by a bone augmentation surgery with anterior iliac crest bone.

In this study, autogenous bone, with the iliac crest as donor site, has been used as grafting material for the sinus floor elevation procedure. Since the start of the study, several systematic reviews

have been published which concluded that xenographic grafting materials only, as well as xenographic materials mixed with autogenous bone, resulted in comparable successful outcomes (Aghaloo & Moy, 2007; Rickert, Slater, Meijer, Vissink, & Raghoobar, 2012). If the iliac crest is no longer needed as a donor site for large amounts of bone, this would obviously lead to less morbidity.

At the start of this trial, cone beam computed tomography (CBCT) was not available at our Medical Center. The bone volume was therefore estimated by analyzing conventional two-dimensional radiographs. Nowadays, the bone volume of the maxilla would have been measured by CBCT, which provides more accuracy in diagnosing the amount of bone necessary for the sinus floor surgery or this could even prevent this procedure.

In spite of the limitation of the current study that analysis was done at implant level and by only one observer, the present 5-year follow-up study shows that bar-connected maxillary overdentures on either four or six implants that are placed in the posterior region of severely resorbed maxilla's, preceded by an augmentation procedure with iliac crest bone, lead to comparable treatment outcomes with high implant survival, limited loss of peri-implant marginal bone and high patient satisfaction.

CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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